Postharvest sweetening of buttercup squash using high temperature treatments

A report prepared for
The New Zealand Buttercup Squash Council Inc.

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1 EXECUTIVE SUMMARY

The taste of squash has been identified by the Squash Council as a priority area for research. Improving sweetness is seen as particularly important for the Japanese market. In 1994, Bycroft et al. showed that the sucrose level in squash heated to 33°C for 7 days was more than two-fold that of fruit stored at 12°C for the same period. This difference remained after five weeks further storage at 12°C. However, heat-treated fruit lost more weight and the skins were lighter in colour than the controls.

During the 1995 season, we heated 500 kg bins of export buttercup squash to 30°C for periods of 2, 3, 5 or 7 days, at Longburn, Palmerston North. We wished to determine whether larger quantities of fruit could be 'sweetened' without the negative effects of weight loss and colour change. Tagged fruit in these bins were either assessed for weight loss, dry matter content, skin and flesh colour, incidence of rots, sugar levels and taste, or stored for a further 21 days at 12°C to simulate transport to Japan. These stored fruit were then assessed using the same parameters.

Two, 5 and 7 days of treatment at 30°C resulted in higher levels of sucrose than equivalent periods at 12°C. After 7 days of treatment at 30°C the sucrose content of the fruit rose to double the level of sucrose in fruit treated at 12°C. Similar higher levels of sucrose were found in fruit held for 5 and 7 days at 30°C plus 3 weeks of storage at 12°C storage.

Glucose and fructose content did not alter significantly during treatment, but increased during subsequent storage at 12°C. Post-storage levels of glucose and fructose were higher in the fruit treated at 12°C than those treated at 30°C.

The heat treatments had little or no effect on dry matter content, which remained between 23 and 28% throughout the experiment. However, dry matter declined slightly during storage at 12°C for three weeks.

The yellow component of skin colour increased slightly during the 12°C treatments. However, the squash treated at 30°C became progressively more yellow with increasing treatment time and this trend continued during storage at 12°C. The skin colour of the heat-treated squash was more yellow and slightly lighter than that of the fruit treated at 12°C.

Flesh colour became more red with time and at the higher temperature, although the difference between the 12°C and 30°C treatments was not great.

Percentage weight loss increased with both time and temperature, although the difference between the 12°C and 30°C treatments was less after further storage at 12°C for three weeks.

A strong correlation was found between sucrose levels in the squash and the sweetness perceived by an experienced sensory evaluation panel. There was no correlation between glucose or fructose and perceived sweetness and they had little or no influence in combination with sucrose. Sweetness ratings increased with treatment time at 30°C compared to 12°C and ratings increased further for both treatments after three weeks of storage at 12°C.

Only three squash decayed during storage, so no relationship between treatment and rots was established.

Heat treatment technology can be used to increase the sweetness of buttercup squash after harvest on a one-bin scale. Commercial application has yet to be tested, but this report provides guidelines to assist in implementing such a system.

To maintain consistent quality production of heat-treated squash, a system for monitoring sucrose content is required. Maintenance of green skin colour is also important. Further studies are required to address these two issues.

2 INTRODUCTION

The New Zealand Buttercup Squash Council believes that squash export volumes from New Zealand have peaked. To maintain market share, it is important that squash exported from New Zealand are of the highest quality. The Council has identified taste, and in particular sweetness, as an important quality parameter.

In a study at Levin Research Centre in 1994, we increased the rate of accumulation of sucrose in harvested buttercup squash by heating the fruit to 33°C for 7 days. However, other effects of this treatment were more rapid weight loss and colour change, neither of which was desirable in squash destined for the Japanese market.

We considered it likely that shorter periods of storage at high temperatures would still result in attaining relatively high sucrose levels, but would reduce the colour change and weight loss effects of the 7 day treatment used last year. We also considered it important to confirm last year's results using a larger volume of squash; develop a treatment protocol for commercial application; and consider heat management implications of the technology.

In this season's experiment, we heated pallet-loads of export grade squash to 30°C at a packing shed in the Manawatu, for up to one week, then stored some fruit at 12°C for an additional three weeks to simulate shipment to Japan. We measured weight loss, dry matter content, skin and flesh colour changes and sugar levels in the fruit. We also ran taste panels to confirm whether higher sugar levels could be perceived as increased sweetness.

3 METHODS

On three separate occasions, one 500 kg bin of export buttercup squash at the Longburn packing shed of BayCrop Ltd was stored at 12°C or 30°C for 7 days in insulated containers. Individually labelled and weighed fruit were distributed throughout each bin. Initially, the sides of the bin and T-bar floor of the container were covered to increase the airflow across the squash and hence their rate of warming. After 48 hours of treatment, the covers on the sides of the bin were removed to reduce airflow and consequent weight loss. Squash temperatures were monitored during the treatments.

After each of nil, 2, 3, 5 and 7 days of treatment, 12 labelled squash were removed from each bin. Six fruit were taken the same day to Levin Research Centre for assessment of a range of quality parameters. The other six fruit were stored for three weeks in an apple box in the insulated container at 12°C, to simulate shipment to Japan. Labelled fruit were assessed for the same quality attributes after this period.

We measured carbohydrate levels (glucose, fructose and sucrose) in the fruit as indicators of sweetness. We also measured the effects of the treatments on weight loss, dry matter content and skin and flesh colour. Colour changes were measured using a Minolta CR200 chromameter and the CIE Lab colour coordinate system. 'L' is a measure of colour intensity, 'a' measures colour on a red-green scale and 'b' measures colour on a blue-yellow scale.

Taste panellists assessed fruit for sweetness after nil, 2, 5 and 7 days of treatment and after further storage at 12°C for three weeks.

4 RESULTS AND DISCUSSION

4.1 Carbohydrate analysis

Sucrose levels were higher after treatment at 30°C than at 12°C, on all sampling occasions (Figure 1). They reached a peak of 257mg/g after 7 days at 30°C and 3 weeks at 12°C. The absolute difference between the two temperature regimes also increased with time of treatment and with subsequent storage at 12°C. Accumulation of sucrose appears to have continued at a high rate even after the fruit treated at 30°C were cooled to 12°C for simulated shipment.

Differences in glucose levels between the two temperature treatments were considerably less than for sucrose, particularly before simulated shipment (Figure 2). Glucose levels increased during shipment, with a peak of 74 mg/g after 3 weeks at 12°C and were 9 to 11 mg/g higher for the 12°C treatment than the 30°C treatment. Overall, levels were lower for glucose than sucrose.

Fructose content was generally less than 50% that of glucose but like glucose, levels were higher after storage than before (Figure 3). Fructose levels were lower in the 30°C treatments than in the 12°C treatments, on all sampling occasions.

4.2 Dry matter content

Dry matter content changed little throughout the experiment, remaining at between 23 and 28% (Figure 4). However, there was a small drop of 1 to 2% after storage.

4.3 Skin and flesh colour

Skin colour, as measured by the b-value, became more yellow with increasing time and temperature (Figure 5). However, the rate of increase was greater for the 30°C -treated fruit than for the 12°C -treated fruit. The colour change in the 30°C, 5 days plus 3 weeks and 7 days plus 3 weeks fruit was particularly rapid compared with the 30°C 2 day plus 3 weeks and 3 days plus 3 weeks fruit.

The skin colour of heat-treated squash was slightly less intense (lower L-value) than was the skin of the fruit treated at 12°C (Figure 6).

The a-value was used to measure flesh colour changes. The flesh became redder with increasing time and temperature, but the colour changes were greater at 30°C than at 12°C (Figure 7).

4.4 Weight loss

Weight loss increased with time and temperature, reaching a maximum of 6.6% after 7 days at 30°C plus three weeks at 12°C (Figure 8).

4.5 Storage rots

Only three squash decayed during storage. This number was too small for the decay to be attributed to any treatment effects.

4.6 Taste panels

Treatment at 30°C resulted in squash perceived by the panel as sweeter (higher rating, Figure 9) than those kept at 12°C. Sweetness also increased with the number of days of heat treatment. The difference between the two temperature treatments became more marked after a further three weeks of storage at 12°C.

Sucrose content and sweetness as perceived by the sensory panel were highly correlated (Figure 10. r^2=0.75, p=0.0001), but there was no significant correlation between sweetness and glucose and fructose.

4.7 Comparison with last season's results

Comparisons were made between squash heat-treated for 7 days in last season's squash experiment and those treated similarly in the current study. Changes in sucrose, fructose and glucose content, dry matter content, and flesh colour were similar between years. In the first 7 days of treatment at 12°C, weight loss occurred at a similar rate to last season (1.48% in 1995 and 1.5% in 1994). However at 30°C, the rate was slower this season (5.4%) than last year (7.5%). This may reflect a higher humidity of the high temperature treatment this season.

4.8 Heat flows

Squash in the bins used in this experiment required 30-40 hours to reach 30°C, using 5 x 900 W heaters. The temperature rise was more rapid during the first 10 hours, increasing from approximately 14°C to 24°C in that time (Figure 11). Air volumes through the pallet were 6-12 cu m/min while the sides of the bins were covered, but were reduced after the covers were removed.

4.9 Application of the technology

To apply this technology on a commercial scale, it is important that the most efficient and uniform use possible is made of the available heat source, particularly when large volumes of produce are to be heated. To achieve this, warm air can be directed through the squash pallets using a method similar to that adopted for forced-air cooling of fresh produce (Figure 12).

If an entire storeroom of squash is to be heat-treated, the bins of squash should be stacked in two rows, three or four pallets high, with a 0.5-1.0 m wide aisle between the two rows. The top and ends of the aisle need to be covered with a canvas or plastic sheet or sheets of plywood. At one end of the corridor, an extractor fan which exhausts to the surrounding storeroom is fitted. Once the storeroom has been heated to 30°C, the extractor fan is started. Warm air is drawn between the slats in the bins, across the squash fruit, into the low-pressure aisle and through the extractor fan. The high airflow through the pallets results in a faster temperature rise and superior heat distribution than simple static heating.

Once the produce has reached 30°C, the fan can be switched off and the cover removed from the aisle. Re-cooling the squash to 12-15°C after the heat-treatment will minimise skin colour change and weight loss.

If smaller quantities of squash are to be heat-treated, insulated shipping containers, such as that used in our study, could be suitable, although each container holds only 16 bins of fruit. Effective sealing of the sides of the bins for the first 24-28 hours will increase airflows and rates of warming of the squash.

In warm climates such as Hawke's Bay or Auckland, consideration should be given to heat-treating squash which is still in field bins, as the squash will generally be warmer than during grading and thus require less heat input to reach 30°C. This method is only advisable where subsequent squash reject rates are expected to be low.

5 CONCLUSIONS

This study confirms many of the results from last year's experiment and provides evidence supporting the benefits of heat treating squash to raise sucrose content and perceived sweetness.

We recommend heat-treating squash at 30°C for approximately 5 days, a time period which will double sucrose levels, raise perceived sweetness, but minimise weight loss and skin colour change. Exporters can, with confidence, market heat-treated squash as being sweeter than conventionally-treated squash and command premiums for that product.

The information on systems for application of the technology will assist squash packing companies to make decisions as to whether heat-treating squash is a commercially viable option for their operation.

6 ACKNOWLEDGEMENTS

We would like to thank: Talebul Islam for assistance in analysis of squash samples, Paul Hurst for biochemical advice, Ross Lill and Donald Irving for commenting on the draft report and the taste panellists for their patience.

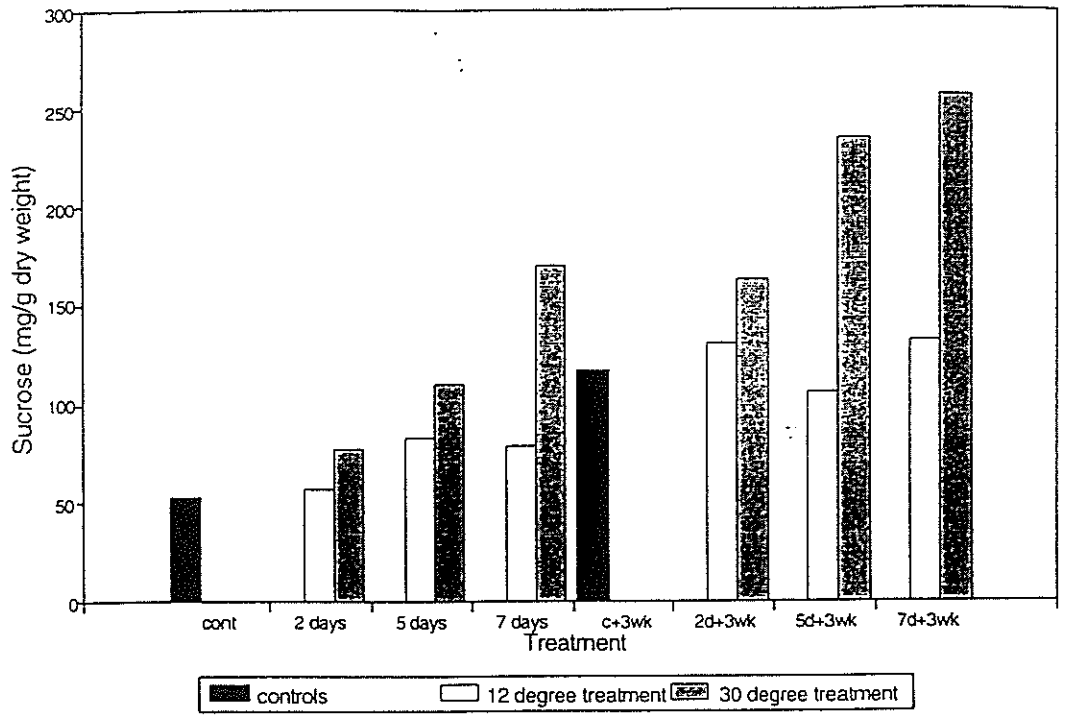

Figure 1. Sucrose levels after treatment at 12°C or 30°C and after a 3 week storage period at 12°C.

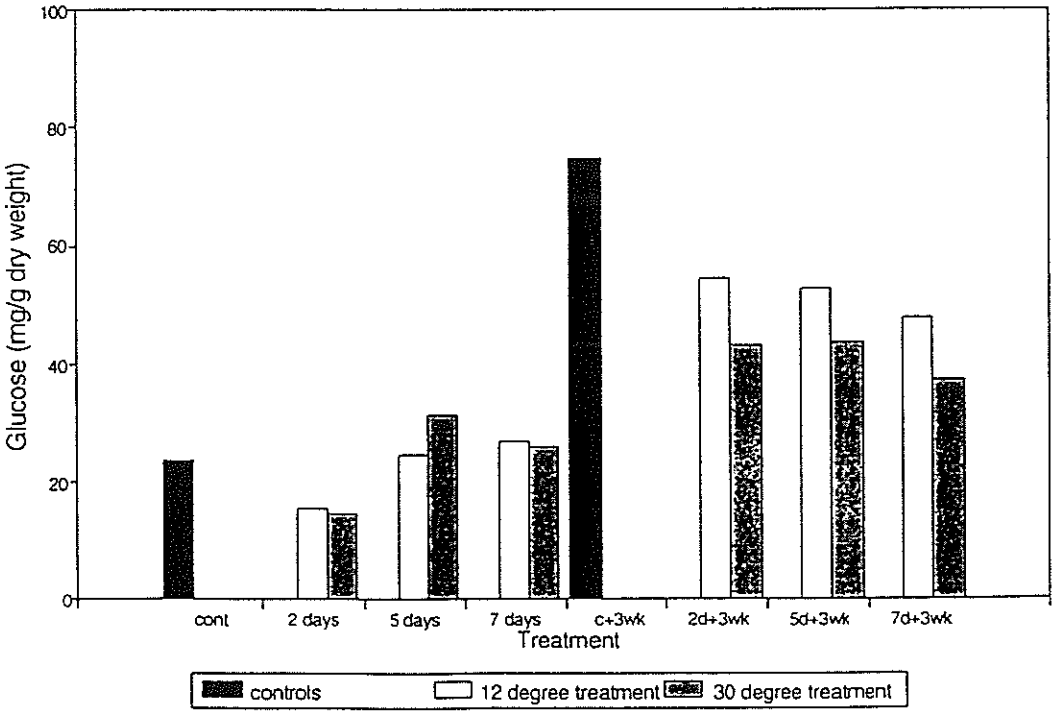

Figure 2. Glucose levels after treatment at 12°C or 30°C and after a 3 week storage period at 12°C.

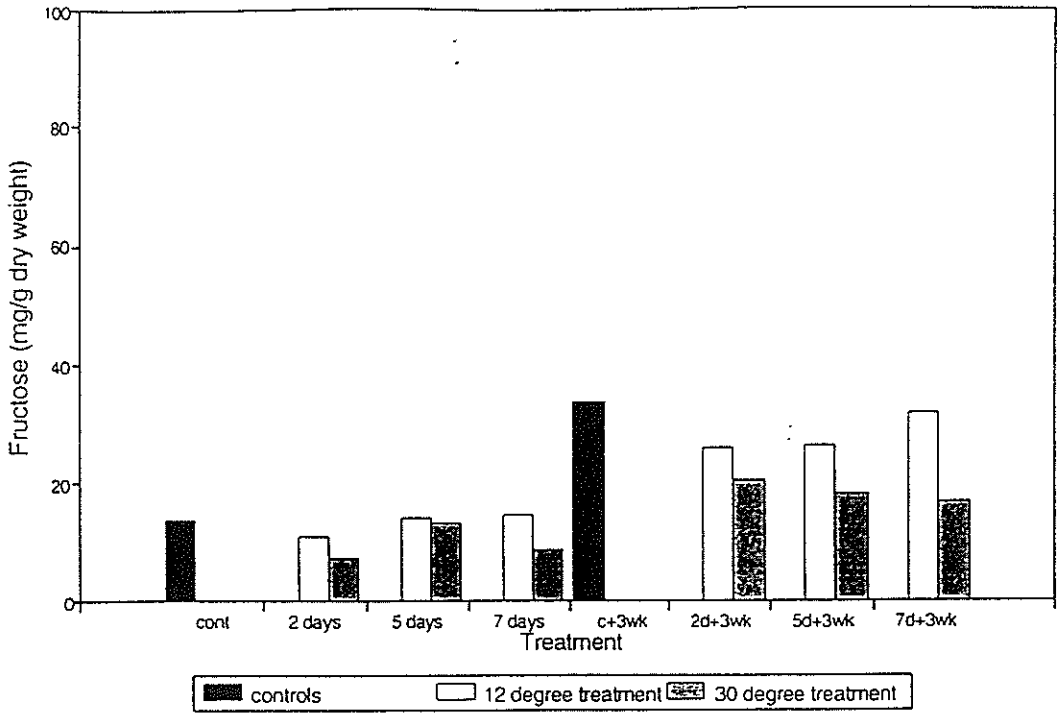

Figure 3. Fructose levels after treament at 12°C or 30°C and after a 3 week storage period at 12°C.

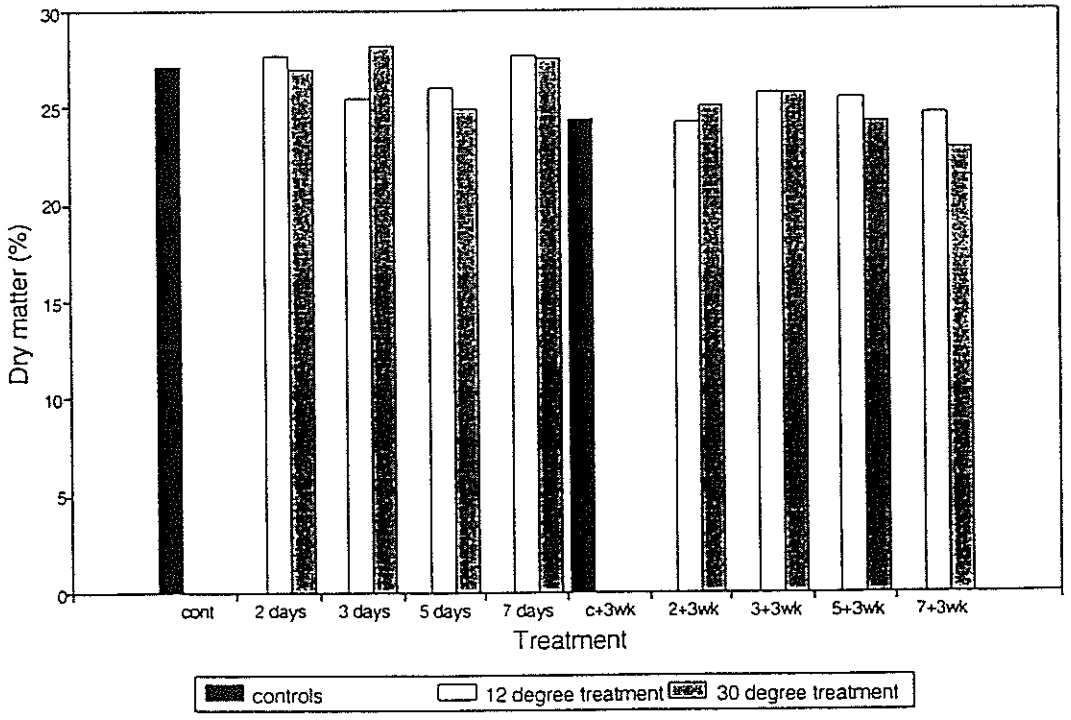

Figure 4. Dry matter content after treament at 12°C or 30°C and after a 3 week storage period at 12°C.

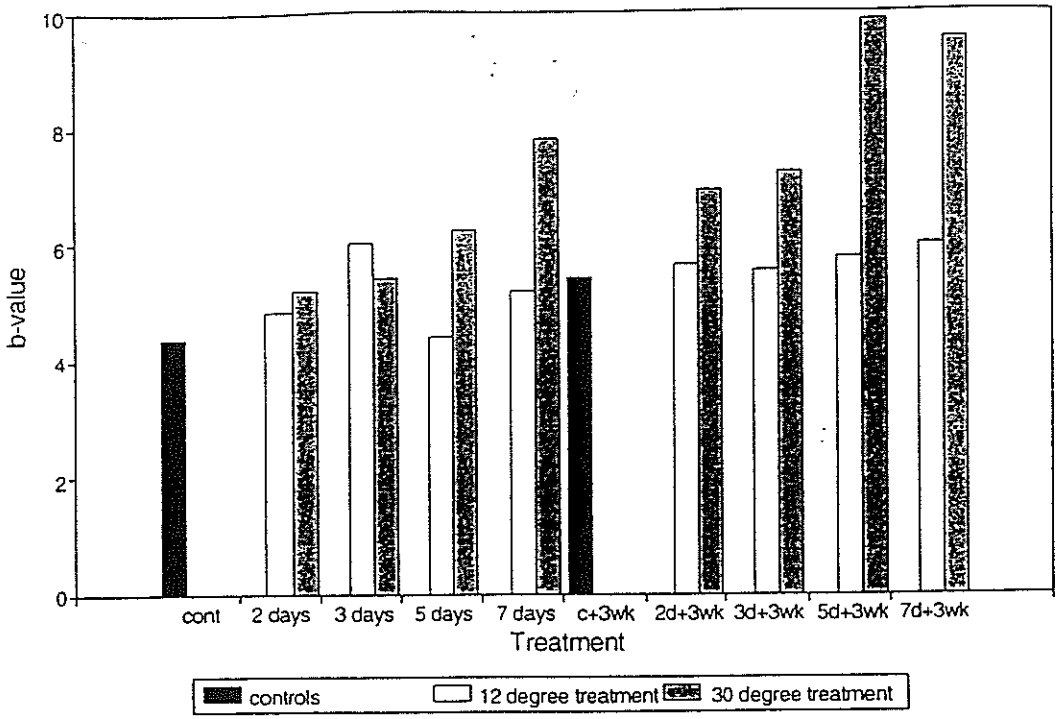

Figure 5. Skin colour (b-value) after treatment at 12°C or 30°C and after a 3 week storage period at 12°C.

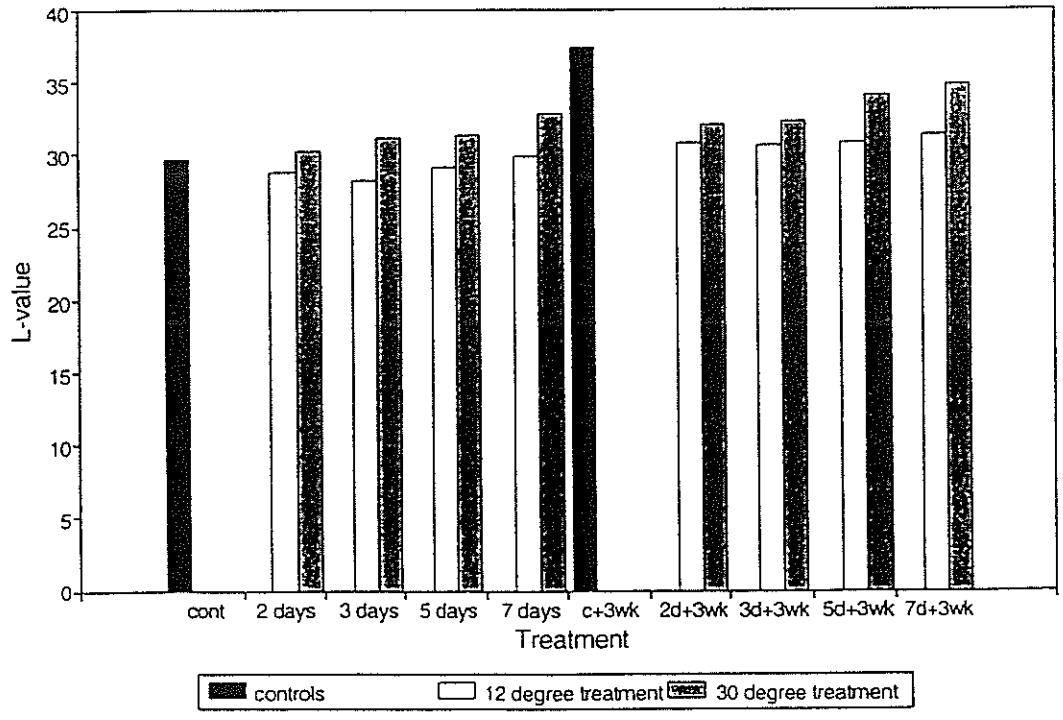

Figure 6. Skin colour intensity (L-value) after treatment at 12°C or 30°C and after a 3 week storage period at 12°C.

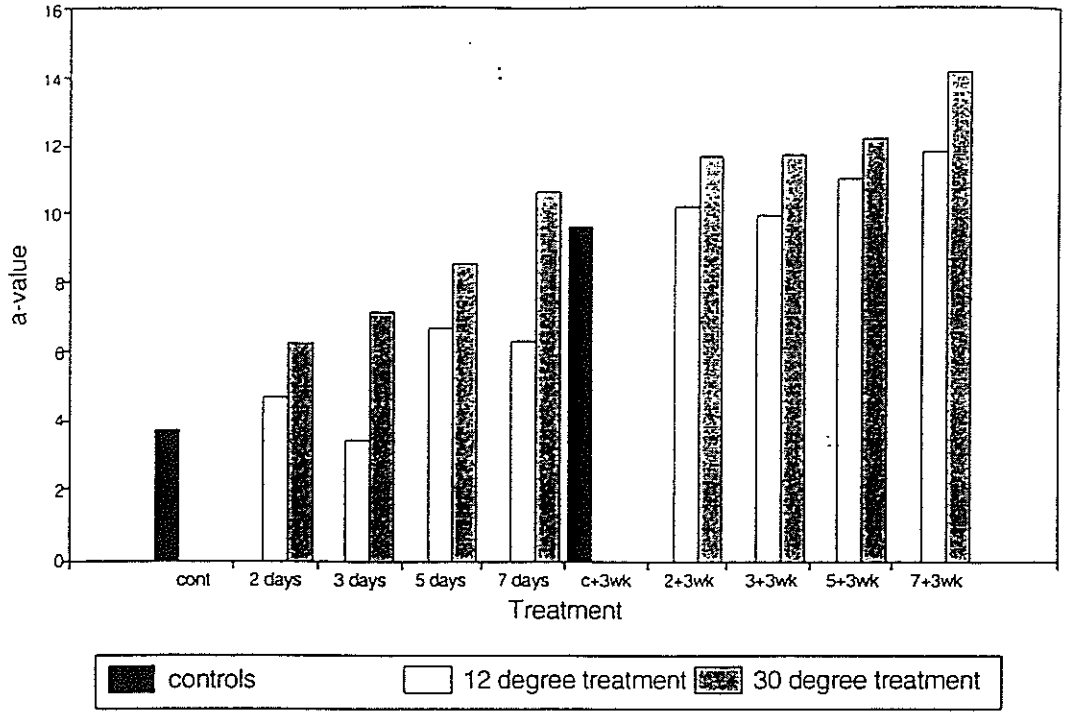

Figure 7. Flesh colour (a-value) after treatment at 12°C or 30°C and after a 3 week storage period at 12°C.

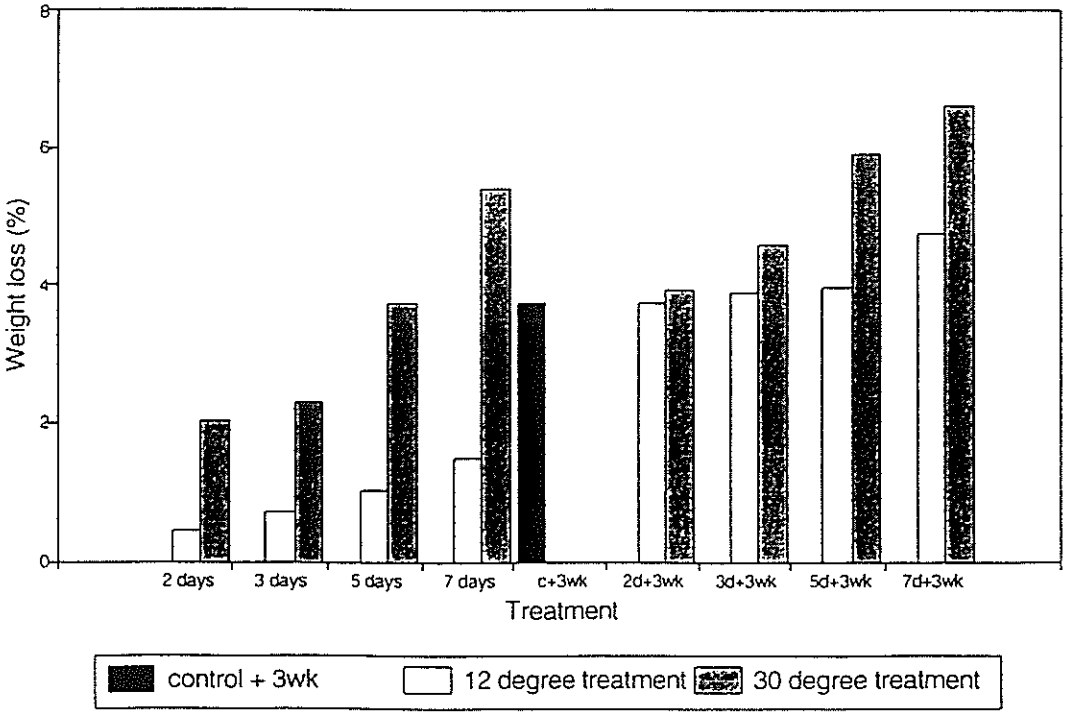

Figure 8. Weight loss during treatment at 12°C or 30°C and during a 3 week storage period at 12°C

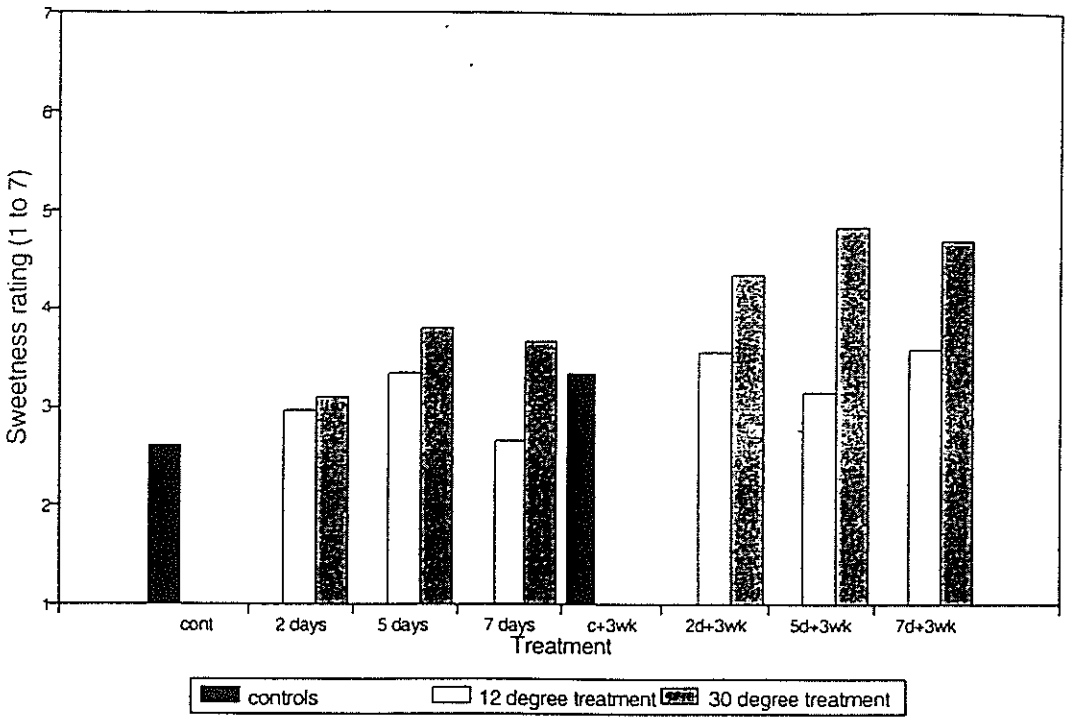

Figure 9. Panel rating of squash sweetness after treatment at 12°C or 30 and after a 3 week storage period at 12°C.

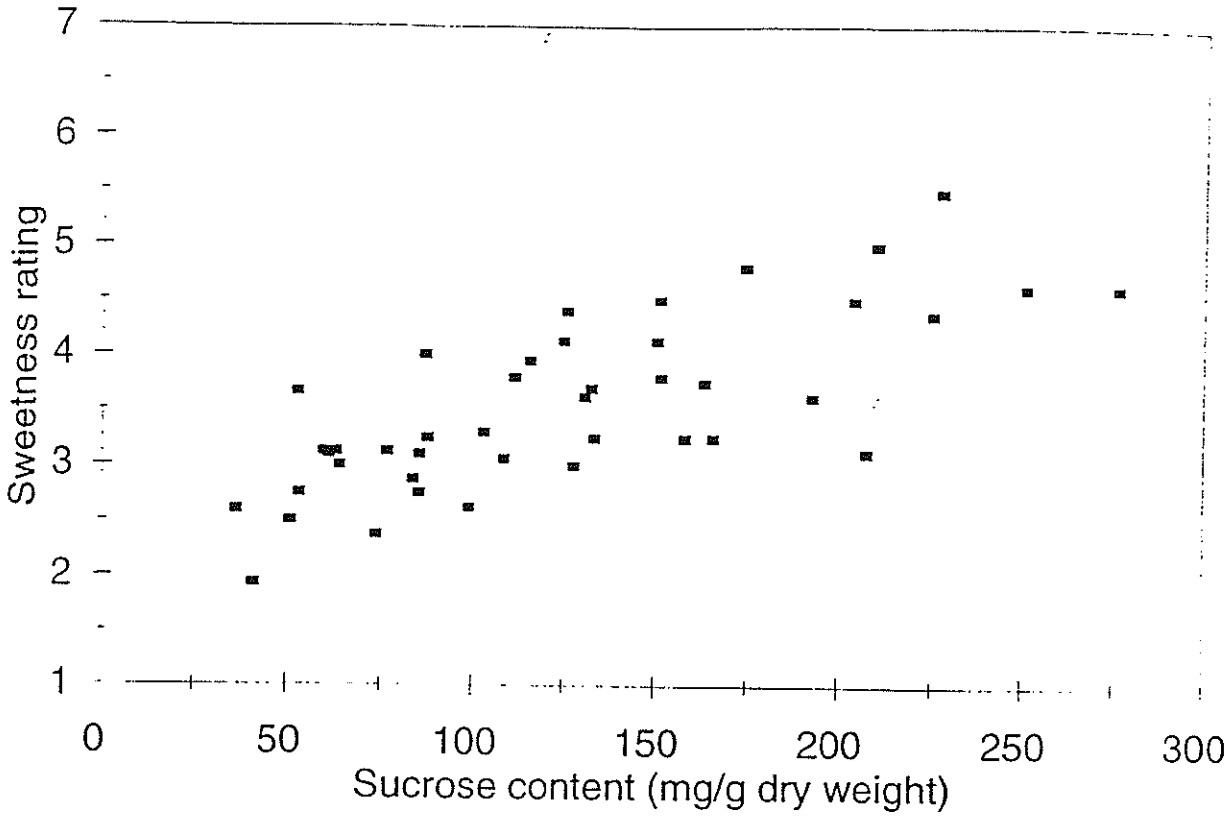

Figure 10. Correlation of squash sweetness with sucrose content. Each point represents the mean of two squash.

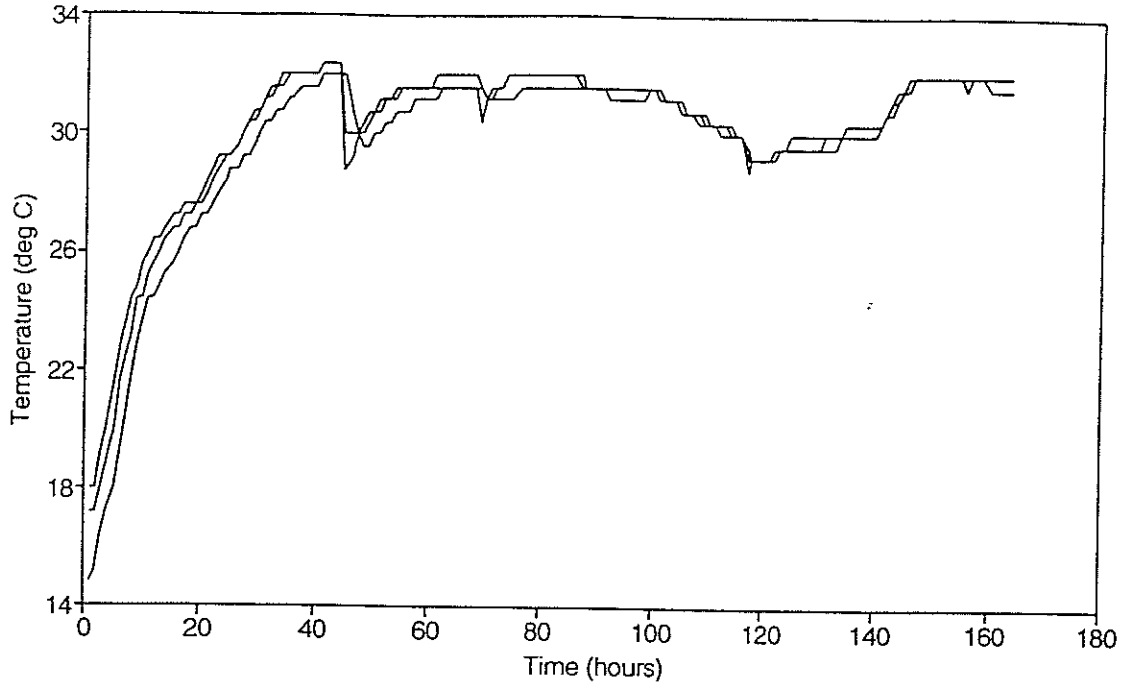

Figure 11. Temperature profile of squash fruit in centre of 500 kg bin and heated to 30°C for 7 days. The three lines represent logged surface, flesh and seed cavity temperatures of the squash. Sharp dips in the temperature profile result from opening the container to remove samples.

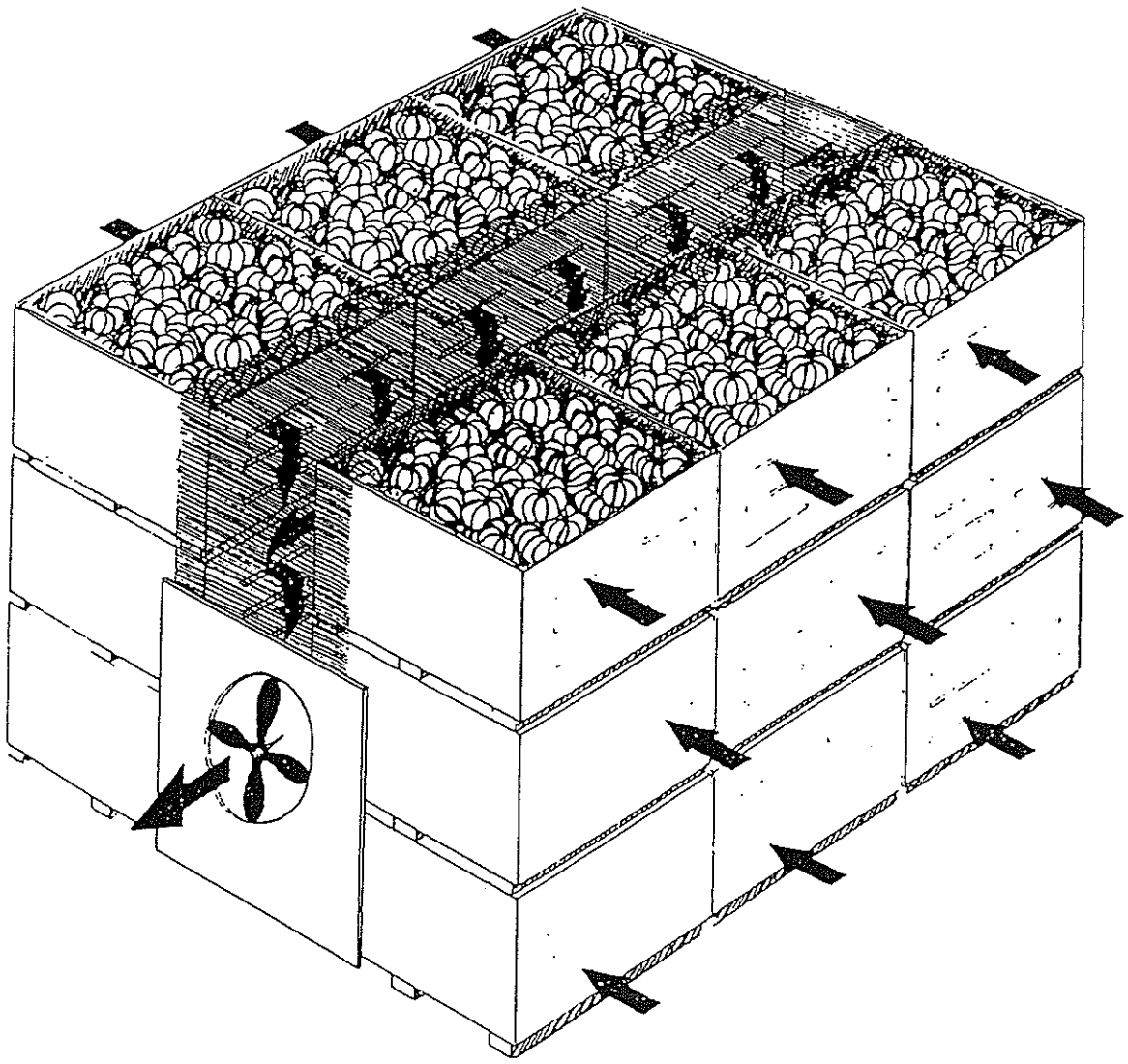

Figure 12. Suggested layout of bins for rapid heat-treatment of squash. Arrows represent airflows through the bins.